

Ultrafast, Ultraintense Laser Microfabrication and Diagnostics

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A breakthrough in ultrafast, ultraintense laser technology is driving the development of a new generation of diagnostic systems that have the potential of aiding the development and evaluation of lifetime prediction models and providing nondestructive inspection of engine/aircraft components. Recent advances in laser technology have resulted in the availability of tabletop, ultrafast (10^{-12} to 10^{-18} second-pulse), ultraintense (10^9 W to 10^{15} W+) lasers (UULs), that cost about \$1M. A few years ago such lasers cost tens of millions of dollars and were housed in mega facilities such as those at the National Laboratories. Because of the extremely short pulse widths and extreme intensities, these lasers have been referred to as Extreme Light (Sci. Am. May 2002). Extreme light interacts with matter in completely new ways that are advantageous for micromachining and a new generation of diagnostic systems. For example, machining with ultrafast lasers is fundamentally different from machining with other laser techniques. Because the laser pulse is extremely short, material is removed by vaporization, with very little heat transfer to the surrounding material. As a consequence, precision machining can be accomplished with minimal stress and thermal cracking of the surrounding material and without formation of recast layers that result from melting. Also, this “near-perfect” machining can be applied to nearly ALL materials. The problem is that the material removal process is currently slow due to the limited average energy of current ultrafast lasers. However, the laser technology is advancing at such a fast rate that ultrafast micromachining is expected to be economically viable in the next few years.

Extreme light interacting with select target materials can result in point sources of penetrating radiation (gamma rays, x-rays, far-ultraviolet and terahertz) and particles (electrons, protons, positrons, neutrons, and ions) that can be used as nondestructive evaluation tools with unprecedented temporal and spatial resolution. Such an extreme light diagnostic system could be used for early detection of cracks and other inclusions in fabricated and fielded components and for use as a research tool to aid the development of component life prediction and design models. Research to optimize extreme light/target interactions to produce radiation and particle sources is just starting. In the next 5 to 15 years this new generation of diagnostic systems is expected to be available for Air Force applications. This poster illustrates some of the features of extreme light and its potential for *reducing costs* and *saving time* through “near-perfect” machining of ALL materials, through early detection and repair of failing components, and through accelerated research and development of advanced weapons systems and the models used to design them. Visions for extreme light diagnostic, machining/diagnostic, and NDE systems are shown below.

